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Synchronizing Legume Residue Nutrient Release with Kale (*Brassica oleracea* var. *acephala*) Uptake in a Nitisol of Kabete, Kenya

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Introduction

Nitrogen (N) and phosphorus (P) are identified as major limiting nutrients for many cropping systems (Kwambiah et al., 2003) and their application from organic and inorganic sources is essential to maximize and sustain crop yield potentials (Hartermink et al., 2000). N is commonly considered a key factor limiting crop growth in organic systems (Möller et al., 2008) and, unlike conventional farming systems, rely on management of soil organic matter to optimize crop production (Watson et al., 2002). Addition of plant residues, quantity wise and timing, has thus become a pivotal strategy in soil fertility improvement for crop production e.g. kales (*Brassica oleracea* var. *acephala*) under organic farming systems.

Chickpea (*Cicer arietinum*) and white lupin (*Lupinus albus* L.) are leguminous crops commonly intercropped with kales (Genga, 2014) and their influence on crop yield and soil nutrient status has been widely studied (Nduku 2014, Genga 2014; Onwonga et al., 2015). There is however a dearth of information with respect to synchronization of nutrient released by legume residues with pattern of nutrient uptake by kales to match their demand. The objective of the current study was therefore to assess decomposition and nutrient release rates of chickpea and lupin residues and kale nutrient uptake patterns for better synchrony of nutrient supply and demand.

Material and Methods

Site description: Kabete field station (latitude 1°15'S, longitude 36° 41'E; 1940 m above sea level; mean temperature 24.3°C - maximum and 13.7°C –minimum; mean annual precipitation 1000 mm) of the University of Nairobi, is located 10 km north of Nairobi and falls in agroecological zone III (Jaetzold and Schmidt, 2006). Soils are deep red nitisols containing 70% clay particles (FAO, 1990).

Agronomic practices, sampling and analysis: Kale seedlings (4 week old) were grown, parallel to legume residue decomposition plots, in pure stands with application of farm yard manure (FYM) (10t/ha). All recommended agronomic practices were applied (Chepkoech, 2015). Legumes, to provide residue after harvest, were previously planted and managed as described by Lelei et al. (2014) in a neighbouring field with 10t/ha of FYM applied. Kale leaves for N and P analyses were sampled from three middle rows at 30, 60 and 90 days after planting.

Decomposition studies: Chickpea and white lupin residues were weighed (proportional to their dry matter production per hectare) and put in litter bags (20 × 20 × 20 cm) without chopping

them, and buried (in triplicates) in soil to a depth of between 10 and 15 cm. The litter bags were retrieved at 0, 15, 30, 45, 60, 75, 90, 105 and 120 days of incubation, residues washed with distilled water to remove soil particles and carefully transferred to khaki bags. The residues were then oven dried, grounded to pass through a 2mm sieve and analyzed for N and P content using standard laboratory procedures.

Determination of weight loss and nutrient release rates: The percent of dry weight remaining after each retrieval was calculated as; $XR (\%) = (XR_t/X_0) * 100$. Where XR = percent weight remaining, X_t = weight content at each sampling time and X_0 = the starting weight values. The decomposition rates were calculated using a first-order exponential decay function, $Y = y_0 e^{-kt}$ (Wieler and Lang 1982). Where Y = the weight or nutrients remaining at time t , y_0 = the initial weight or nutrients available before the decomposition, k = the decomposition constants, t = time of decomposition. The half-life ($t_{1/2}$) was calculated using the equation; $T_{1/2} = \ln(2)/k$. Where $t_{1/2}$ = time when half of the nutrients or weight is lost, $\ln(2)$ = natural logarithm and k = decomposition rate.

Results and Discussion

Residue Weight loss: Legume residue weight loss (days), with days of incubation, was rapid (0-30), moderately rapid (30-60), moderate (60-90) and gradual (90-120). About 30 (first 15 days), 50 (after 45 days) and 86.5% (at 120 days) weight loss was registered for both residues (Figure 1).

The drastic weight loss in the first 30 days could be attributed to high content of fast decomposable components such as sugars, amino acids and proteins and with progress of incubation, recalcitrant materials increase (Berg et al. (2007)). The calculated half-life for both legumes was 52 days.

Nutrient release rates: The N release was rapid (first 30 days), moderate (30 and 75 days) and gradual (75 to 120 days) (Figure 2A). There was a 10-33, 50 and 80 - 86.7% loss of N by chickpea and lupin within the first 15, 30-60 and 120 days, respectively. The N half-life (N release) was 20 days.

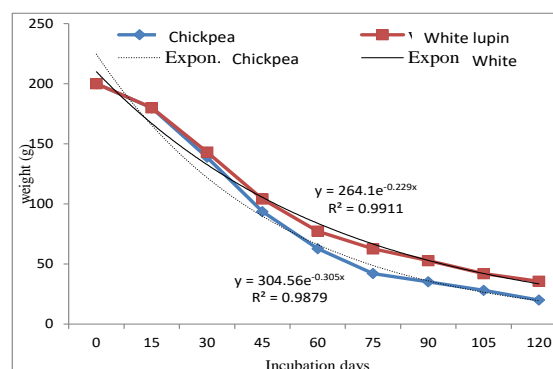


Figure 1: Weight losses of chickpea and white lupin within 120 days of soil incorporation

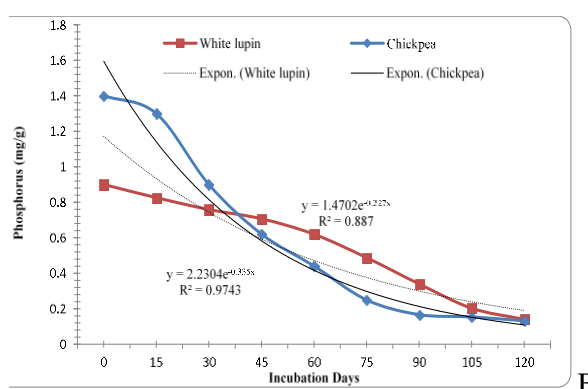
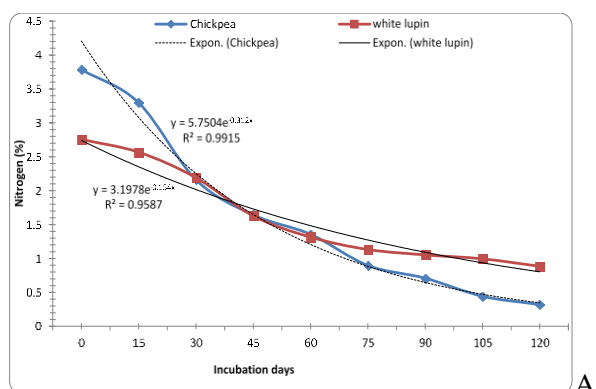


Figure 2: Nitrogen (A) and Phosphorus (B) release of chickpea and lupin residues in 120 days of incubation

The rapid release of N by chickpea (C/N=24) and white lupin (C/N=26) residues can be attributed to high initial N contents and lower C/N ratios (see also Danga et al., 2010). Shi (2013), reported that C (%) of decomposing residues decreased with increase of incubation days.

The P release (days) was rapid (0-15), moderately rapid (15 and 45), moderate (45 and 75) and gradual (75 and 120) for chickpea and lupin, respectively. About 50 % loss of P occurred between 15 and 30 days corresponding to 33.3 and 38.8% and 3.5 and 1.7% of initial P in lupin and chickpea (Figure 2B), (see also Mburu et al. (2013). The P half-life was 30 days.

Kale nutrient uptake

During kale growth (Figure 3), nutrient uptake was rapid (0-30 days), followed by a moderate phase (30-60) and progressive decline (60-120 days). Nutrient uptake was significantly correlated with kale growth (Figure 4). Rapid nutrient uptake in first 30 days of growth is a factor of more

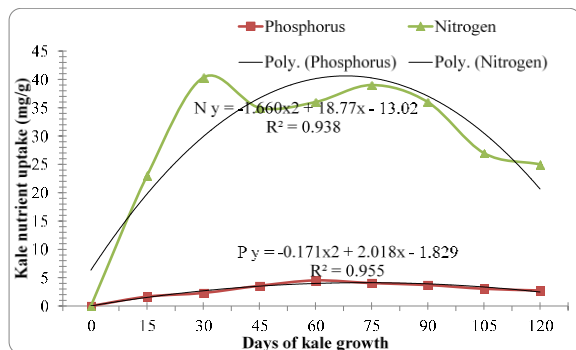
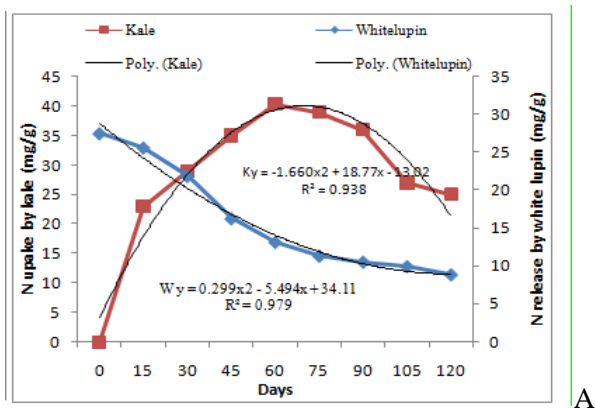


Figure 3: Nutrient uptake by kale in 120 days of growth

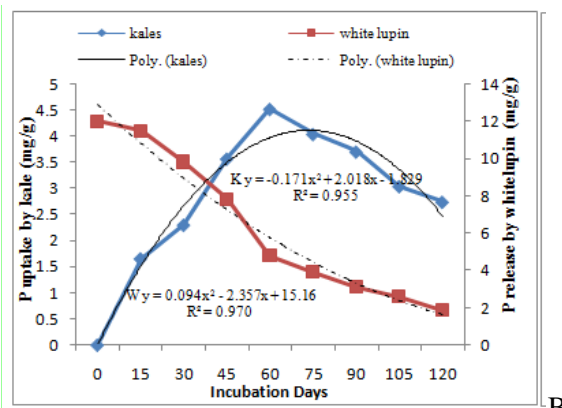
uptake.

leaves being produced and hence more nutrients needed. Highest concentration of nutrients in kale leaves was recorded between day 30 and 60 (see also Salisbury and Ross 1992).

Legume N and P release compared with kale uptake: The N and P release by legume residues curves (Figures 2A and B) were superimposed on kale nutrient uptake curves (Figure 3) with a view of determining the point at which they intersect, herein interpreted as optimum synchrony of nutrient release with



A



B

Figure 4: Kale nitrogen (A) and phosphorus (B) uptake in relation with nutrient release by white lupin

The N release by chickpea and white lupin, and uptake by kale intersected at day 25 and 30, respectively (Figure 4A and B) with the intersection of P for both legumes being at day 30. The N and P release rate were significantly correlated ($R^2=0.970$) to uptake by kales (Figure 4).

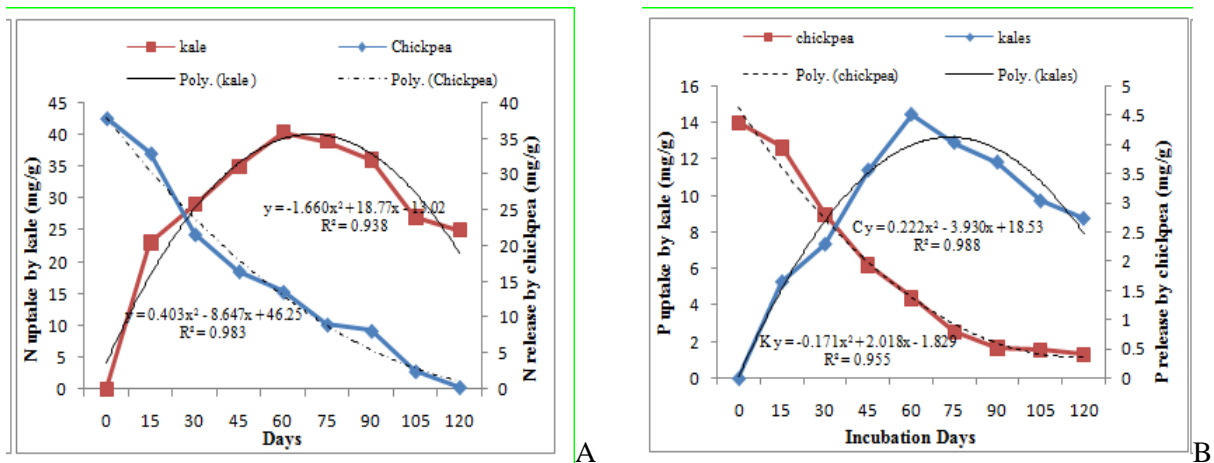


Figure 4: Kale N (A) and P (B) uptake in relation to nutrients release by chickpea

The nutrient release and kale nutrient uptake curve superimposition results, closely mirrored the findings from the calculated half-life of N (20) and P (30). As described by Palm et al. (2001) and Rowe et al. (2004), strategies in legume-based systems to potentially reduce the rate of N supply around periods of potential asynchrony include changing the timing and placement of legume residues, manipulating residue quality through choice of legume tissue or species.

Conclusions and Outlook

Weight loss of legume residues was rapid (0-30 days), moderately rapid (30-60), moderate (60-90) and gradual (90-120). About 10-33, 50 and 80-86.7% loss of N by chickpea and lupin was realized in 10-15, 30-60 and 120 days, respectively. Approximately 50% of P released occurred between day 15 and 30 for both legumes. Kale leaves had higher N and P concentrations/uptake from day 30 to 60. Half-life for N and P was at day 20 and 30, respectively. Similarly, the N and P release by chickpea and uptake by kale intersected at day 25 and 30, respectively. Chickpea and white lupin residues have the potential to provide nutrients upon mineralization but for maximum nutrient synchrony between nutrient release and kale nutrient uptake, the legume residues should be incorporated in soil at kale seedling (4 weeks old) transplanting to optimize on residue benefits and minimize loss of available nutrients.

Acknowledgement

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